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DIFFERENCE OF TOOL WEAR OF COATED AND UNCOATED TOOLS ON TITANIUM ALLOYS

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Abstract:
As is recognized widely, tool wear is a major problem in the machining of difficult-to-cut titanium alloys. Therefore, it is of significant interest and importance to understand and determine quantitatively and qualitatively tool wear evolution and the underlying wear mechanisms. The main aim of this paper is to investigate and analyse wear, wear mechanisms and surface and chip generation of uncoated and TiAlN-coated carbide tools in a dry milling of Ti6Al4V alloys. The effect of cutting speed and feed rate on tool wear (tool life) and surface roughness of the TiN coated carbide inserts was experimented. For coated tools the tool life obtained was relatively higher values. The coated tools exhibited a better performance for shorter cutting lengths, producing a lower degree of roughness on the surface on the machined material. The wear registered for these tools was less intense than that of uncoated tools, which suffered more adhesive and abrasive damage. However, it was observed that, for greater cutting lengths, the uncoated tool performed better in terms of surface roughness and sustained wear.
Key words: Tool wear, Titanium alloys, carbide tools
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I. INTRODUCTION:

Machining processes are a viable option for the fabrication of these parts; however, there is little research conducted in this area, especially directed at machining optimization of these alloys and at the study of the wear behavior of tools applied in the machining of copper-beryllium and copper-based alloys [1]. Understanding the wear behavior of cutting tools is quite beneficial as it provides information on the machinability of materials, and insights on what strategies to use, the best tool types, and even the most indicated tool coatings to machine a certain material By evaluating the wear mechanisms and machining performance of certain tools, providing knowledge on how wear is developed throughout the cutting process, the optimization of the machining process of a certain material becomes possible this is particularly useful when considering hard-to-machine materials, such as nickel-based alloys [2,3]. These studies offer insights on optimal machining parameters and the wear mode that tools undergo enabling the selection of more adequate machining strategies, the development of new tools, or even application of the correct cooling method Studies such as these are also quite beneficial when it comes to choosing the right type of coating for a machining application, as they provide knowledge that is invaluable to produce new designs for tools and coatings Regarding machining optimization, there are a number of numerical and simulation methods that have proven useful in this regard; for example, using the Taguchi method to optimize certain machining parameters to obtain a better desired result, such as improving material removal rate surface roughness and even tool wear [3,4]. These studies offer insight on the optimal machining parameters, even relating coating thickness and structure to the process' outputs Other numerical methods

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rely on simulations, for example, the finite element analysis, offering predictions on the machining outputs and enabling further optimization, especially if paired with other optimization methods, such as the Taguchi method or grey relational analysis Tool coatings have proven to be quite an improvement in the machining process, especially in turning and milling processes however [5,6]. these can be applied to a wide variety of other metal-cutting processes, such as tapping, where the use of hard-coatings has provided a viable solution for tapping hard-to-machine materials by essentially improving tool life and cutting behavior These coatings directly impact the wear behavior and performance of cutting tools lowering the produced surface roughness, sustaining wear, and even decreasing the cutting forces that are generated during the process One of these coating types that deserves some attention are diamond coatings used in machining as these significantly improve the wear behavior of cutting tools and there have been some recent developments, further improving wear resistance by employing multilayered structures. [7,8] These directly improve the wear resistance of coatings, as the structure types confer the tool with properties such as improved thermal dissipation and improve crack propagation resistance, thus improving the overall tool's life and performance Still, regarding the wear performance of coated tools, the influence of the tool's substrate plays a significant role in the performance of a cutting tool. A poor substrate surface quality can produce defects during the deposition process that hinder the coated tool's performance, promoting premature coating wear the tool's substrate can also be improved, for example, by employing mechanical treatments before the deposition process these pretreatments are known to improve coating adhesion to a substrate, thus improving the wear behavior of the coating.

II. Experimental details

The machining was conducted on the workpieces made of Ti6Al4V alloys. The chemical compositions and mechanical properties of the material are presented in Table The as-received material block was cut into a size of 100 mm × 150 mm × 80 mm ($L \times W \times H$). The top and bottom surfaces of the specimen were further rough machined with a very shallow cut to clean and even out the surfaces. This process used a 10,12 mm diameter solid carbide indexed cutter running with a feed rate of 600, 800 mm/min and a spindle speed of 1500, 2000 r/min.

Table: Chemical composition of Ti6Al4V alloy

Element	w(Ti)/%	w(Al)/%	w(V)/%	w(Fe)/%	w(C)/%
Value	Balance	6.15	4.40	0.09	0.05

Tool wear

The main focus is to investigate the tool wear and wear mechanism associated with machining titanium alloy. In general, the cutting tests continue until the tool reaches a standard failure criterion, i.e., average flank wear is 0.3 mm for carbide tool. depicts a comparison of the tool flank wear progression with respect to the cutting length for the uncoated and coated tools. It can be seen from that, as the cutting length increases, TiAlN-coated carbide tool exhibits a lower wear than the uncoated tool. For instance, after a cutting of 10 m, the coated tool reaches a wear value of 150 mm, which is about 32% smaller than that of the uncoated tool wear 12 mm). The coated tool can cut up to 22 m in length with wear progression of about (10 mm, while the uncoated tool reaches wear of about 0.321 mm (i.e., failure criterion) at a shorter cutting distance of 16 m. Overall, the coated tool, generally after a cutting of 16 m, shows an enhancement of tool life by about 44% over that of its counterpart.

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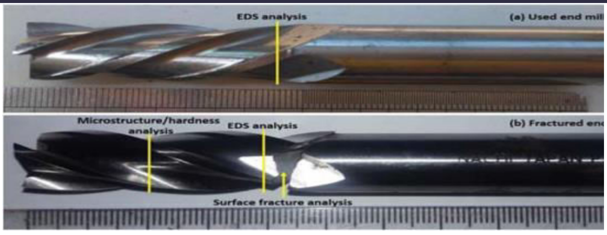

Figure: Tungsten carbide end mills used in the tests

Wear mechanisms

In order to evaluate the machining performance of the cutting tools, an understanding of the underlying wear mechanisms is essential. The wear and wear mechanism vary with the combination and interaction of the cutting tool and the workpiece, in addition to the cutting environment. As titanium is hard material, the wear mechanisms that influence the failure of carbide tools may be different from those when machining other materials

III. TOOLS WEAR ANALYSIS:

After the machining tests and tool preparation, they were submitted for SEM analysis. In this way, it was possible to identify and quantify the level of wear on the cutting tools used in the tests. For this analysis, and as mentioned Carbide 10mm,12mm Dia tools was used. For cutting tool analysis, it was necessary to create labels, as shown in Figure 1, where each cutting knife is identified with a number. Figure 1b represents the analysis of the cutting knife's number 1 rake face. This labeling allows an easy analysis and identification of the cutting knife under study. Throughout the study, it was necessary to create labels in order to simplify the no

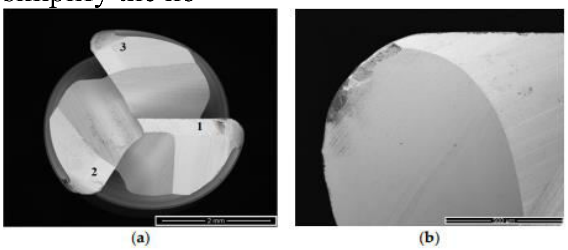

Figure: Positioning and lebelling used the tools' analyses: (a) Label used in the tools' analyses; (b) label used for rake face of cutting tool

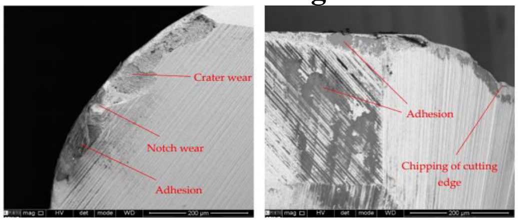

Figure: (a) Wear mechanisms registered on the rake face sustained by an uncoated tool tested at a cutting length of 100mm and 600 feed rates; (b) wear mechanisms registered on tools' top sustained by an uncoated tool tested at a cutting length of 48 m and 1500 mm/min feed rate

The main wear mechanisms that these coated tools suffered were coating delamination, adhesion, and tool chipping, for both feed rate conditions. However, for higher feed rate values, considerably more chipping damage to the tool was registered, as seen in Figure (b, which negatively impacting the machined surface roughness. For lower feed rate values, the main mechanisms were adhesion, coating delamination, and chipping of the cutting edge.

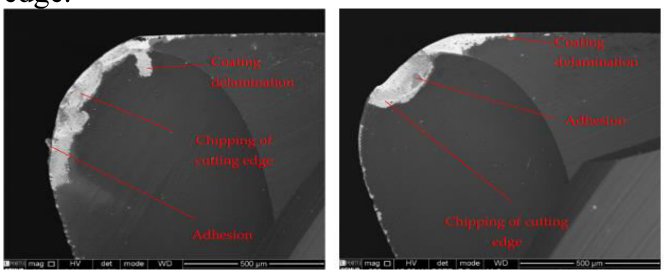

Figure: coated tools rake face tested at a cutting length of 150 mm, at 220× magnification: (a) for a coated tool tested at a feed rate value of 800 mm/min and (b) coated tool tested at a feed rate value of 2000 mm/min.

Discussions:

The experimental results of an investigation on the effect of cutting speed and feed rate on tool wear and surface roughness to optimize the machining conditions for turning applications using the TiN coated carbide inserts are presented. In addition, a comparison is made between TiN coated carbide inserts and uncoated carbide inserts in terms of tool wear and surface roughness for the same machining conditions. Surfaces of cemented carbide cutting tools need to be abrasion resistant, hard and chemically inert to prevent the tool and the work material from interacting chemically with each other during machining. Cutting tools with regards to tool life travel path, the required power for machining, and the surface quality of the generated workpieces improves remarkably using coated cemented carbide cutting tools Layers of titanium carbide (TiC), titanium nitride (TiN), titanium carbonitride (TiCN), titanium aluminum nitride (TiAlN), and aluminum oxide (Al2O3) are most commonly used when machining metals The cutting speed significantly affects the machined surface roughness values. With increasing cutting speed, the surface roughness values decreased Higher values of feed rates are necessary to minimize the specific cutting force. The machining power and cutting tool wear increases almost linearly with increase in cutting speed and feed rate.

Conclusion:

the coated and uncoated tools presented similar wear behaviors, with the coated tools exhibiting less wear and producing a better machined quality in the beginning of the tests. However, for longer cutting lengths the coated tools were outperformed by the uncoated ones, producing a worse surface finish and suffering more wear The tool's wear behavior was similar with an increase in the feed rate values, with the sustained flank wear being more severe for a feed rate value of 1500 mm/min. A flank wear of 80.71 µm and 102.3 µm was registered for uncoated and coated tools, respectively. These maximum flank wear values were registered for higher cutting lengths, with the coated tools experiencing considerably more wear for higher cutting lengths than the uncoated tools. However, for cutting lengths of 100 and 150 mm, these tools exhibited less wear than the uncoated ones. Thus, it seems that the 10mm cutting length represents a turning point for the tools' wear behavior. For the 48-m cutting length, the uncoated tools presented a better behavior than the coated ones, thus, the improved behavior of the coated tools ends at about a cutting length of 12 mm.

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